Impact of Foreign Exchange Risk on International Portfolios

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The purpose of this article is to illustrate the impact of foreign exchange risk on international investments such as well diversified portfolios of assets. The centre part of this study is the Value at Risk (VaR) model, computed with the variance-covariance approach and assuming non-normality of returns and conditional volatility. The analysis is made on relative VaR (RVaR), the most important type of VaR, with a time horizon of 1 week and a 95% confidence level. The results indicate that currency movements have a major impact of on international portfolios, a finding that is supported by the unpredictable nature of FX rates and their nonexistent correlation with foreign equity returns. Also, establishing a general rule regarding currency risk will be of great use when dealing with hedge instruments.

Key words: *currency risk, value-at-risk, Cornish-Fisher approximation, EWMA, component VaR, future contracts*
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I. Introduction

Any well established financial institution faces many types of risk. As companies expand, develop into new fields and open branches abroad, their risk and exposure to financial instruments increases accordingly. Let us take a simple example of an UK established firm that wants to invest £1.000.000 in bonds. Only this transaction alone increases the

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liquidity, interest rate and default risk exposures. If the bonds happen to be issued in US, then we also add an increase to the foreign exchange risk.

In fact, at any one time, a well-known financial institution faces four main types of financial risk: liquidity risk, market risk, credit risk and operational risk. Liquidity risk deals with how easy you can buy and sell instruments on both sides of the balance sheet (i.e. asset liquidity risk and funding liquidity risk). When one talks about market risk, one refers to the risk of unfavourable price changes in equity, interest rates, commodity and, of course, foreign exchange. Credit risk is divided between counterparty default risk and migration risk, the risk that a company will be downgraded and receive a lower rating (e.g. from AA to BBB). Finally, operational risk is defined as the risk of loss resulting from inadequate or failed internal processes, people and systems or from external events. Each type of risk is computed in a distinct way, either by using the same concept or by using different risk management tools. It is thus easy to see that risk managers have a lot of work to do.

Most financial and non-financial firms are especially preoccupied to manage the market risk of their portfolios and they must constantly be up to date with their market exposure. This is no easy thing to do because assets and derivatives generally have more then one type of risk. At the beginning, market risk was looked at in isolation (i.e. the main market segments: equity, bond, currencies, derivatives, commodities, emerging markets, etc.) and did not take into account correlation benefits. Therefore, there was a strong necessity to integrate all the risk information and present it as a single number. This is what gave rise to the Value-at-Risk model or simply VaR model.

One of the first institutions to build, implement and make public a VaR model was the US commercial bank J.P. Morgan. At the end of the eighteen century, the then Chairman of the bank demanded that he should receive a summary piece of information, in a single monetary value, concerning the whole bank's market risks in the main market segments and the diverse geographical regions where the bank had branches. Accordingly, the bank's risk managers pioneered VaR, a measure of the maximum loss that an asset or portfolio of assets can sustain, given a particular confidence level (lower than 100 %), over a predetermined time period. Put differently, VaR answers a very useful question: "What is the maximum loss which could be sustained over a particular time window, so that there is a very low probability (ex: 1% for a 99% confidence level) that the actual loss will exceed this amount?"

In recent years, Value-at-Risk has become the standard tool used by financial institutions to measure and manage risk. Currently, VaR is used primarily for measuring market risk but can also be used to compute credit risk. However, there has been an increasing interest in using the VaR concept as a tool for managing and regulating credit risk and as a methodology for constraining and controlling the risk exposure of a portfolio.

II. A Brief Literature Review

The starting point for this analysis is based on A. Resti and A. Sironi (2007). As one of the best risk management books, it emancipates us in understanding the VaR model for market risk together with its limitations and applications. Two methods are presented, the variance-covariance approach and the simulation models approach (Historical and Monte-Carlo).

Although briefly described in the above mentioned book, volatility modelling is best presented in Christoffersen (2002). His book aggregates all the theoretical background for conditional volatility estimation. In this regard, we only mention the Exponentially Weighted Moving Average (EWMA) model which was introduced by JP Morgan's RiskMetrics system in 1996.

In addition, Christoffersen (2002) provides information about and suggests the use of non-normal distribution of returns when computing VaR by presenting the Cornish-Fisher approximation. Also, one should not disregard the work of Jorion (2000), an acknowledged VAR expert, which provides further insight on financial risk management and the VaR models.

Many tests have been and are still made over which approach works better but no precise result are found as each one has both advantages and disadvantages. For the purpose of this article, the variance-covariance approach is used as the most popular and easy to compute method. The main reasons consist in the reliance on portfolio returns and volatility, which make it easier to observe the impact of each asset of the portfolio on VaR.

The results of Codirlasu (2007) and Iorgulescu (2009), PhD students at the Academy of Economic Studies, Bucharest, prove the reliance of the models used in this article. In his thesis, Codirlasu (2007) provided a comparable analysis among different portfolio volatility estimations and concluded that the EWMA approach performed best. Iorgulescu (2009) proved in his article that assuming non-normality of returns will greatly impact the value of VaR, making it more dependable.

III. Methodology of the VaR Model

At the beginning of this article, VaR is defined as the loss in portfolio value, over a period of time, at a given level of confidence. As an example, if the level of confidence is 95% then the weekly VaR is that loss that is exceeded only 1 week in 20.

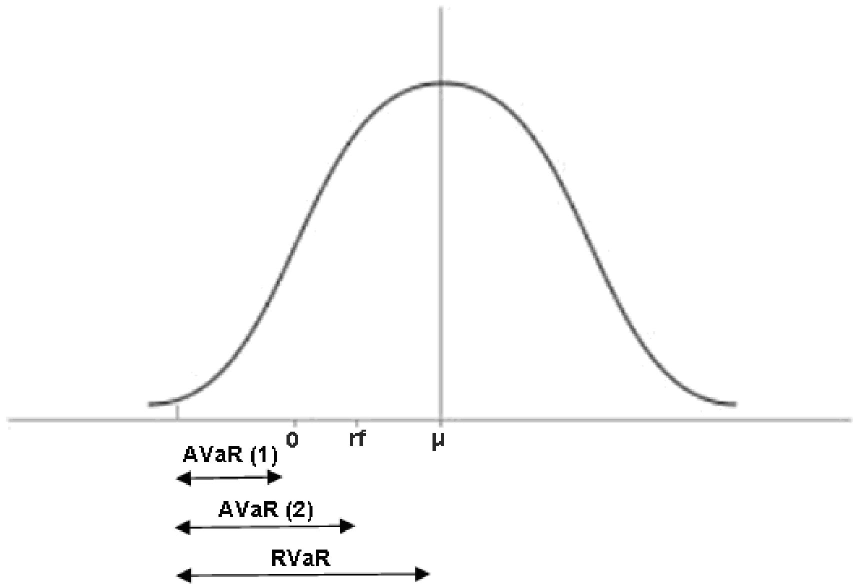
VaR can be expressed using two notions, either absolute or relative. Absolute VaR (AVaR) from zero gives the maximum drop in portfolio value, over the VaR time period and at a given level of confidence. As one would expect to get at least the risk-free rate (rf) when investing in a portfolio, absolute VaR from rf is a more appropriate measurement.

But the best type is the relative VaR (RVaR) because it assumes that the portfolio should recompense not only for the time value of money (i.e. realise the risk-free rate) but also for the riskiness of investing in shares (i.e. realise the risk premium).

The VaR is closely connected to the probability or frequency distribution of returns. Because losses are negative returns, we are only interested in the left side of the distribution (See Figure 1).

Figure 1

Distribution of portfolio returns



To attribute a numeric value to our VaR, the only amount we have to calculate is the fall in portfolio value, or negative return R*. The R* of a (1 − p)% VaR (whether absolute or relative) is implicitly defined as the negative return such that the cumulative probability to its left is equal to p. Formally,

$$P(R < R^*) = \int_{-\infty}^{R^*} f(R)dR = p$$

In the above formula, P ( ) is the probability operator and f (R) denotes the probability (or frequency) distribution of portfolio returns.

VaR without the assumption of normality

When we look at asset returns we usually observe they have a non-normal distribution. As a matter of fact stock returns are characterised by fat tails (i.e. kurtosis is higher than 3, which is the value in normal distributions) whereas bond returns have fat tails and negative skewness (skewness is zero in normal distributions). Other financial instruments such as options have highly non normal returns. These facts alone prove that VaR should take into account these distortions from the standard normal distribution.

Thus, greater precision can be attained by using the information given by the estimated skewness (S) and kurtosis (K) from portfolio returns[1]. With the help of the Cornish-Fisher approximation, VaR can include such information and at the same time keep the formulas resulted under the normal distribution case. Under normality, (1 − p)% RVaR has the following formula:

$$\mu - R^* = -\Phi^{-1}(p)\sigma$$

In the above formula, μ and σ are the portfolio mean and the portfolio volatility and $\Phi^{-1}(\ )$ is the inverse of the standard normal cumulative distribution function. Using the Cornish-Fisher approximation, all one

[1] $S = \frac{1}{\sigma^3(n-1)}\sum_{i=1}^{n}(R_i - \mu_R)^3$; $K = \frac{1}{\sigma^4(n-1)}\sum_{i=1}^{n}(R_i - \mu_R)^4$

needs to do is to replace $\Phi^{-1}(p)$ with $\Phi^{-1}_{CF}(p)$ which is defined as follows:

$$\Phi^{-1}_{CF}(p)=\Phi^{-1}(p)+\frac{S}{6}\left(\Phi^{-1}(p)-1\right)+\frac{K-3}{24}\left([\Phi^{-1}(p)]^3-3\Phi^{-1}(p)\right)-\frac{S^2}{36}\left(2[\Phi^{-1}(p)]^3-5\Phi^{-1}(p)\right)$$

It is important to observe that the Cornish-Fisher approximation is just a generalised form of the inverse of the standard normal cumulative distribution function When we plug S = 0 and K = 3 (as specified in a normally distribution) into the formula it shows that $\Phi^{-1}(p)=\Phi^{-1}_{CF}(p)$.

Choosing VaR parameters (t,p)

The choice of t (i.e. holding period or time horizon) and 1 − p (i.e. confidence level) depend on how or why VaR is used. One can look at VaR as a relative measure of risk. If VaR is used to compare risk among different portfolios or for the same portfolio over different time periods then any acceptable (t, p) can be used.

If one looks at VaR as an absolute risk measure, then t should reflect the time frame needed to unwind the positions taken in the portfolio. This is very hard to do during a market crash because everyone does the same thing. Concurrently, t should also be contingent upon how often the portfolio structure is modified. In general, banks use a time window of one day but pension funds use higher time frames of one week or one month.

The confidence level is set to maintain or acquire a certain credit rating. The target rating accounts for the level of risk aversion taken by the bank or fund.

When deciding t and p, one also looks at Backtesting, a testing process to find how accurate the VaR model is. Because the number of observations is smaller the higher the confidence level, the VaR estimate can be less precise. The form of the density function far out in the left tail is very important as it gives the chance of incurring large losses. Moreover, we have less observations when we choose a longer time window and this could also result in a less accurate VaR.

VaR Models for Market Risks

VaR for market risk portfolios is generally calculated using two methods: the variance-covariance approach and simulation approaches. Under the first, the VaR can be computed more precise when advanced estimation methods for computing the variances-covariance matrix are used. Although the variance-covariance method is based on normality and stable distribution over time, these assumptions can be both relaxed. Moreover, this method makes it easier to compute Component VaR (a risk management indicator).

The second approach refers to Historical simulations, Monte Carlo and Stress testing. Historical Simulations has the advantage of being based non-normal distribution of portfolio returns but assumes stable portfolio distribution over time. The Monte Carlo approach captures the non-normality portfolio distributions but is computationally intensive. Stress testing is usually used as a managerial tool to investigate how the bank or fund reacts to explicit risk factors or events.

Conditional volatility estimations models

Usually, the volatility of the assets in the portfolio is not stable over time. As a matter of fact, conditional volatility (i.e. time varying volatilities) should be used as it may explain the non-normality of asset returns. Two of the most popular ways of computing conditional volatilities are the moving averages (MA) and the GARCH models.

We will not continue with explaining the MA as they have the "echo effect" or "ghost features" problem. This happens when high volatility occurs on the short-run (e.g. for just a few weeks) and is not expressive for the state of the market continuing this event. Because the MA weights equally all observations, it will register a much higher value then in reality until the high volatility event exits the MA time period.

To address the above problem one should use a GARCH (Generalized Autoregressive Conditional Heteroskedasticity) model. The advantaged of the GARCH method are that it provides a balance between stability and the necessity to capture the current tone of the market. Exponentially Weighted Moving Average (EWMA) is one of the best versions of the GARCH model. When using EWMA to calculate the conditional volatility, past observations are weighed less than more current return observations. Weights decrease exponentially as one looks further back in time. The EWMA conditional volatility has the following formula:

$\sigma_t = \sqrt{\frac{1-\lambda}{1-\lambda^T}\sum_{i=1}^{T}\lambda^{i-1}R_{t-i}^2}$, where λ is called the decay factor.

Choosing λ can be very difficult. For a low λ, return weights ($\frac{1-\lambda}{1-\lambda^T}\lambda^{i-1}$) decay rapidly and non-current observations will have little effect on the conditional volatility. But for a high λ, return weights decay slowly and non-current observations will still have significant impact on conditional volatility.

Thus, one should choose a higher when the volatility of the portfolio under analysis is higher and a lower λ when the volatility is more stable. Also, the time frame of the portfolio manager is also important when choosing λ. For a short term view (e.g. daily trades), most recent observations are the most significant when computing volatility. This is the reason why a lower λ would be favoured. For a long term view, portfolio managers should choose a higher λ.

The decay factor is not the only factor undergoing a trade-off. This happens also for the time window of the observations (T). On one hand, T should be large to limit the small sample bias. On the other hand, T should be small to decrease the probability of structural breaks that can have great impact in the conditional volatility estimation process.

If we are to use time varying volatility, then we must also compute time varying covariances ant the EWMA conditional covariance is given by the following formula:

$$\sigma_{jk,t} = \frac{1-\lambda}{1-\lambda^T}\sum_{i=1}^{T}\lambda^{i-1}R_{j,t-i}R_{k,t-i}$$

Risk Management Tools

The most important task of a risk manager is to set risk limits on individual portfolios in line with the amount invested in them. After the portfolio VaR is established, it is very helpful to find how much each asset of the portfolio impacts the total portfolio VaR. A portfolio manager should know which assets are more to blame in case the risk limit is exceeded.

The most popular ways to measure the contribution of an asset to total portfolio VaR are Individual VaR (or IVaR) and Component VaR (or CVaR). The individual VaR of asset X is defined as:

$\Phi^{-1}(1-p)|V_X|\sigma_{t,PD} = \Phi^{-1}(1-p)\sigma_{t,AI}$, where V_X denotes the amount invested in asset X, PD means per dollar and AI denotes total dollar. The reason why we take the absolute value of V_X is to also account for short position on asset X (VaR should always be positive or zero). The main problem with IVaR is that it disregards the correlation between assets.

Component VaR is favoured to IVaR because it solves with the above problem. Component VaR of asset X is defined as:

$\Phi^{-1}(1-p)\frac{\sum_{j=1}^{3} V_j \sigma_{Xj,PD}}{\sigma_{P,AI}} V_X$ or $\Phi^{-1}(1-p)\frac{\sum_{j=1}^{3} V_j \sigma_{Xj,AI}}{\sigma_{P,AI}}$, when re-stating in terms of total dollar covariances.

The best feature of CVaR of an asset in a portfolio is that it gives the approximately change in portfolio volatility if the asset was eliminated from the portfolio. It is essential to note that aggregating all component VaRs of all assets in the portfolio will equal to the total VaR. This is the main reason why this tool in very helpful when studying how much does an asset contribute to portfolio VaR.

$$\Phi^{-1}(1-p)\frac{\sum_{i=1}^{3}\sum_{j=1}^{3} \sigma_{ij,AI}}{\sigma_{P,AI}} = \Phi^{-1}(1-p)\frac{\sigma_{P,AI}^{2}}{\sigma_{P,AI}} = \Phi^{-1}(1-p)\sigma_{P,AI}$$

IV. VaR Practical Application

Fund managers are continuously preoccupied with making profitable investments as this will increase their client database and their access to more funds. By charging fixed fees for his services, a fund manager will have a bigger payroll when his funds beat the market or outmatch other peers. At any one time, a fund manager invests in a variety of financial instruments ranging form domestic and international equities, fixed income securities (i.e. government debt, investment grade bonds and high yield bonds) and cash/money market instruments to real estate, private equity, venture capital and hedge funds. The key problem faced by a fund manager is how much of the investor's wealth should be invested in any of the above mentioned.

Asset allocation is never easy. As economic conditions constantly change, so do the investment preferences of fund managers. They are always looking for new ways to achieve bigger returns through international diversification, strategic asset allocation and tactical asset allocation.

When looking only at equities, the biggest percentages of the funds are invested in the United States, the United Kingdom and Japan. Thus, constructing a fictitious portfolio using these countries' most significant indexes will result not only in a good and well diversified portfolio that mimics closely the returns of real portfolios but also in a representative one for the investment preferences of the average fund manager.

Data Base

For simplicity, let us take the case of a UK pension fund manager that invests 1000000 in the S&P 500 (a US capitalisation-weighted index), the FTSE 100 (a UK capitalisation-weighted index) and the Nikkei 225 (a Japanese price-weighted index). Of course, this portfolio will be exposed to the price movements in the dollar per pound and the yen per pound exchange rates. Taking historical prices for the past 10 years using the Bloomberg Website provides more then enough data to estimate an accurate value for VaR. Prices are taken weekly as daily observations would have been to many for us to capture significant price fluctuations.

Table 1

Weekly past prices from 07/01/2000 to 07/05/2010

Date	Nikkei 225 Index	S&P 500 Index	FTSE 100 Index	GBPUSD Currency	GBPJPY Currency
1/7/2000	18193.41	1441.47	6504.8	1.6393	172.7
1/14/2000	18956.55	1465.15	6658.2	1.6313	172.7
1/21/2000	18878.09	1441.36	6346.3	1.6487	172.74
1/28/2000	19434.78	1360.16	6375.6	1.6201	173.54
2/4/2000	19763.13	1424.37	6185	1.5918	170.61

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4/16/2010	11102.18	1192.13	5743.96	1.5363	141.61
4/23/2010	10914.46	1217.28	5723.65	1.5377	144.49
4/30/2010	11057.4	1186.69	5553.29	1.5274	143.31
5/7/2010	10364.59	1110.88	5123.02	1.4804	135.55

Working with a pension funds, the fund manager is quite risk adverse and will surely care about his exposure to foreign exchange risk. He will try to at least keep the time value of his clients' investments constant and does not want any factors in his portfolio that he cannot easily control (i.e. foreign exchange rates). Therefore, we are very interested in the effects of currency risk on our total return and especially when the portfolio incurs losses.

Before observing how much the foreign exchange risk contributes to the potential portfolio losses, one must first compute Value at Risk. The VaR approach used by most pension funds is the variance-covariance VaR and a common level of confidence interval is 95%[1].

Computations

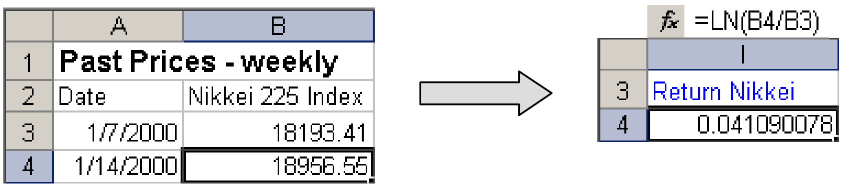
Beginning our computation of relative VaR, we must first compute the weekly returns for our three indexes and for the foreign exchange rates. When calculating returns, it is better to use the geometric method because geometric returns are consistent with the normality assumption and they can easily be calculated over multiple periods by summing single period returns. For example, we can look at a 3-period geometric return $R_{t,3}$ and using simple mathematics one can obtain the following:

$$R_{t,3} = \ln\left(\frac{P_t}{P_{t-3}}\right) = \ln\left(\frac{P_t}{P_{t-1}}\frac{P_{t-1}}{P_{t-2}}\frac{P_{t-2}}{P_{t-3}}\right) = \ln\left(\frac{P_t}{P_{t-1}}\right) + \ln\left(\frac{P_{t-1}}{P_{t-2}}\right) + \ln\left(\frac{P_{t-2}}{P_{t-3}}\right) = R_t + R_{t-1} + R_{t-2}$$

[1] There are some pension fund managers that are more adverse to risk. This is the reason why they increase the confidence level to 97.5.

Figure 1

Example of computing one geometric return



When one invests in international securities, one also invests the same amount in foreign exschange. This is the reason why the weights attributed to the abroad instruments are the same as the ones attributed to the respective foreign exchange rates. After computing all returns for the whole period, we can easily determine the weekly portfolio returns using appropriate weights. Once these are computed, we can find the skewness and kurtosis of the distribution using Excel functions SKEW and KURT.

Figure 2

Skewness and Kurtosis under a scenario

	O	P	Q	R	S	T
1		**Computation of weekly portfolio returns**				
2						
3						Portfolio returns
4						0.023293058
5		**Assets**	**Weights**			-0.026499991
6		**Nikkei**	20%			-0.013605519
7		**S&P**	30%			-0.006678952
8		**FTSE**	50%			-0.004222904
9		**FX GBPUSD**	30%			-0.00413009
10		**FX GBPJPY**	20%			-0.00289296
11						0.030181057
12						-0.001531272
13		**Skewness**	-1.611483262			0.011958081
14		**Kurtosis**	15.71382018			0.03657106

The last piece of information needed to compute the inverse of the Cornish-Fisher cumulative distribution is the inverse of the standard normal cumulative distribution ($\Phi^{-1}(1-p)$). Using Excel function NORMSINV, $\Phi^{-1}(1-p)$ remains fixed at approximately 1.64 for a confidence level of 95%.

Figure 3

The inverse of the Cornish-Fisher cumulative distribution

	Q	R	S
16	**Inverse of the standard normal**		**Confidence level**
17	**cumulative distribution**		95%
18		1.644853627	
19			
20	**Inverse of the Cornish-Fisher**		
21	**cumulative distribution**		
22		**1.797578603**	

Next, we concentrate on the second part of the RVaR formula and estimate the conditional volatility of the portfolio, σ_t. Using the EWMA model with a decay factor (λ) of 0.96 we can build a very accurate variance-covariance matrix given the time horizon of 10 years. Normally, one uses a decay factor of 0.94 when estimating daily volatility and a decay factor of 0.97 when estimating monthly volatility[1].

Thus, λ should be somewhere between 0.94 and 0.97 when estimating weekly volatility. Although the most recent financial crisis ended in 2009, its effects are still felt today as millions of people still struggle to cope with the new economic conditions. This is the reason why more recent economic data is very representative for computing volatility. We even observe from the news how the 2008 financial crisis has transformed into a crisis of the governments. Therefore, a decay factor of 0.96 is fairly expressive for the near future.

[1] Source: Table 5.9, page 100 in the RiskMetrics Technical Document, Fourth Edition, 1996.

Figure 4

Weekly portfolio volatility based on EWMA

	W	X	Y	Z	AA	AB
549		*Return Nikkei*	*Return S&P*	*Return FTSE*	*Change GBPUSD*	*Change GBPJPY*
550	Return Nikkei	**0.001116996**	0.00063881	0.000699182	0.0002072	0.000502865
551	Return S&P	0.00063881	**0.000846181**	0.000823879	0.000166734	0.000387266
552	Return FTSE	0.000699182	0.000823879	**0.000966212**	0.000176261	0.000413819
553	Change GBPUSD	0.0002072	0.000166734	0.000176261	**0.000244141**	0.000310304
554	Change GBPJPY	0.000502865	0.000387266	0.000413819	0.000310304	**0.000682597**
555						
556		**Proportions (m) for an invested ammount of**			1000000	
557		**Nikkei**	**S&P**	**FTSE**	**FX GBPUSD**	**FX GBPJPY**
558		200000	300000	500000	300000	200000
559						
560	**EWMA weekly total dollar variance-covariance matrix**					
561		*Return Nikkei*	*Return S&P*	*Return FTSE*	*Change GBPUSD*	*Change GBPJPY*
562	Return Nikkei	**44679834.1**	38328574.13	69918223.16	12432027.42	20114616.14
563	Return S&P	38328574.13	**76156262.89**	123581904	15006038.98	23235989.62
564	Return FTSE	69918223.16	123581904	**241552998.5**	26439119.8	41381905.76
565	Change GBPUSD	12432027.42	15006038.98	26439119.8	**21972648.99**	18618244.73
566	Change GBPJPY	20114616.14	23235989.62	41381905.76	18618244.73	**27303881.05**
567						
568						
569	**Weekly portfolio Variance based on EWMA**			**Weekly portfolio Volatility based on EWMA**		
570		1189778913			34493.17198	

Now we can compute RVaR and the risk management tools. The benefits of correlation can be clearly observed when looking at the sums of individual and component VaR (RVaR drops from £73459.56 to £62004.19 or by 18.47%). By dividing component VaR of the foreign exchange rates by the relative VaR and multiplying by 100, we can observe how much of the relative VaR is explained by the currency risk.

Figure 5

Relative VaR, risk management tools and the impact of FX

	AS	AT	AU	AV	AW	AX	AY
4	Weekly portfolio Volatility based on EWMA			34493.17198			
5	Inverse of the Cornish-Fisher			1.797578603			
6	cumulative distribution						
7	RVaR (£ m)	62004.18791					
8							
9							
10		Nikkei	S&P	FTSE	FX GBPUSD	FX GBPJPY	Sum
11	Individual VaR	12015.5503	15687.0291	27937.92239	8426.148311	9392.908283	73459.55839
12	Component VaR	9665.761989	14399.56675	26206.8045	4923.113459	6808.94122	62004.18791
13	Component VaR %	15.59%	23.22%	42.27%	7.94%	10.98%	100.00%
14	Total Impact of FX on RVaR					18.92%	

In conclusion, when investing 20% of the amount in the Japanese index, 30% in the US index and the remaining in the UK index, the total impact of foreign exchange is 18.92%. But this number alone is not significant. As one invests more in international equities, it is only normal to for the impact of currency risk on RVaR to also increase. In order to establish a tendency, we must make notes of other scenarios by investing different amounts in our assets.

Constructing a grid that contains all possible combinations of weights attributed to the three assets and computing the average of these will give a fairly good representation of the impact of foreign exchange risk on RVaR. The full grid is built by investing a minimum of 5% and a maximum of 90% in any index. Scenarious differ by adding 5% to one weight and subtracting 5% from another.

Table 2

Impact of FX on RVaR of all scenarios

	AR	AS	AT	AU	AV
17		Full Grid			
18		Nikkei Weight	S&P Weight	FTSE Weight	Impact of FX on RVaR
19		5%	5%	90%	3.39%
20		10%	5%	85%	6.05%
21		15%	5%	80%	8.86%
22		20%	5%	75%	11.76%
.	.	.	.		
.	.	.	.		
.	.	.	.		
34		80%	5%	15%	38.60%
35		85%	5%	10%	39.87%
36		90%	5%	5%	41.03%
.	.	.	.		
.	.	.	.		
.	.	.	.		
187		5%	85%	10%	27.14%
188		10%	85%	5%	29.73%
189		5%	90%	5%	28.59%
190					
191				Average	26.23%

Of course, one cannot consider a well diversified portfolio if 90% of the amount is invested in just one place. A portfolio in which a minimum weight of 20% is attributed to any of the three assets is more preferred. This does not oppose any of the anterior operations as all is needed is to choose the scenarios that respect the new condition and build another grid.

Table 3

**Impact of FX on RVaR of scenarios that have minimum weights of
20%**

	AW	AX	AY	AZ	BA	BB
17		Partial Grid containing only weights over 20%				
18		Nikkei Weight	S&P Weight	FTSE Weight	Impact of FX on RVaR	
19		20%	20%	60%	15.97%	
20		25%	20%	55%	18.88%	
21		30%	20%	50%	21.71%	
22		35%	20%	45%	24.40%	
23		40%	20%	40%	26.95%	
24		45%	20%	35%	29.33%	
.		.	.	.		
.		.	.	.		
.		.	.	.		
58		20%	50%	30%	24.89%	
59		25%	50%	25%	27.55%	
60		30%	50%	20%	30.07%	
61		20%	55%	25%	26.35%	
62		25%	55%	20%	28.96%	
63		20%	60%	20%	27.80%	
64						
65				Average	26.91%	

Results and Comments

The value of 26.91% confirms the fact that foreign exchange plays, on average, a major part in portfolio losses. Although we initially invest in only three assets, we can see that foreign exchange rates work as a forth asset. The movements in foreign exchange contribute approximately one forth to the RVaR of the portfolio. We can easily conclude that currency risk is a very important factor that shouldn't be left uncheck.

Even after we have excluded exaggerate scenarios (such as investing 90% in Japanese shares), the impact of foreign exchange remained nearly constant. The difference between 26.23% and 26.91% is very small and can be perceived as insignificant. Therefore, currency risk contributes, on average, to approximately a quarter to the losses incurred by an international portfolio.

These results have been computed using sound principles (i.e. assuming non-normality and estimating volatility using a GARCH model) that make our VaR model more precise. We can observe their contribution by taking the portfolio composed with the weights described in Figure 2.

Figure 6

Comparison between non-normal RVaR with conditional volatility and RVaR assuming normality and normal volatility

	BD	BE	BF	BG	BH	BI
40						
41		Relative VaR assuming non-normality and estimated volatility with EWMA				
42						
43		Weekly portfolio Volatility based on EWMA			34493.17198	
44		Inverse of the Cornish-Fisher cumulative distribution			1.797578603	
45						
46		RVaR (£ m)	62004.18791			
47						
48		Relative VaR assuming normality and estimated volatility with equal weights				
49						
50		Weekly portfolio Volatility			28229.19343	
51		Inverse of the standard normal cumulative distribution			1.644853627	
52						
53		RVaR (£ m)	46437.02319			

Looking at Figure 6, one can notice the vast differences between the two computational models. Assuming non-normality and estimating volatility with EWMA offered an increase in the RVaR of roughly 33.52% under this scenario. This rise in RVaR is normal when takeing into consideration that we just passed through a financial crisis. It reflects the fact that non-normality and conditional volatility give more precise results.

One can go even further and derive a formula for the impact of FX on portfolio VaR based on the weights invested in international assets. Doing a regression on the data from the full grid confirms the linear relation between these factors (see Table 4). The formula Y = 0.008 + 0.47*(%weight invested in Japanese yen) + 0.28*(%weight invested in US dollar) will yield a good estgimation for the %impact of FX on RVaR (Y). Also this will cancel the need for risk management tools with complex formulas such as component VaR.

Table 4

Regression matrix between %weights invested internationally and the %impact of FX on RVaR

	BO	BP	BQ	BR	BS
16		*Coefficients*	*Standard Error*	*t Stat*	*P-value*
17	Intercept	0.00830441	0.002593011	3.202612802	0.001629267
18	Nikkei Weight	0.476592576	0.004270103	111.6115039	1.6356E-159
19	S&P Weight	0.285396395	0.004270103	66.83595697	5.943E-123

The low probabilities (P-value) show that the regression coefficients are significantly different form 0 and that the model is valid from a statistical point of view. The second and third coefficients give the volatility of the impact of FX for a 1 unit change in the %weight invested in Jamanese yen and, respectively, in the %weight invested in US dollar. Because of a higher risk when investing in the Jamanese currency, the yen volatility (0.47) is evidently superiour to the doillar volatility (0.28).

We all know that foreign exchange rates are characterised by unpredictable movements. Also, when computing the correlations between foreign exchange rates changes and international assets returns, one can notice very small values. When other time periods are chosen, the correlations are closer to zero or even slightly negative. This strongly supports the belief that foreign exchange rates move independently when compared to the general trend of assets returns in overseas countries.

Table 5

Correlation matrix between returns

	Return Nikkei	Return S&P	Return FTSE	Change GBPUSD	Change GBPJPY
Return Nikkei	1				
Return S&P	0.548771024	1			
Return FTSE	0.582988263	0.818755722	1		
Change GBPUSD	0.211204511	**0.167125369**	0.110667539	1	
Change GBPJPY	**0.32635133**	0.294702582	0.293650988	0.660717041	1

All the above findings support the idea that currency risk is very dangerous on ones' investment and, therefore, should be hedged. Using futures is preferred as they have zero value at the beginning of the contract and the only amount that has to be invested is the initial margin.

Usually, the initial margin is set by the exchange at 10% of the total value of the contracts and is paid back at the end of the contract if the FX rate remains unchanged. Taking again the portfolio composed with the weights described in Figure 2, we can calculate the total value of the contracts as 26.91% multiplied with the amount invested in the portfolio. Thus, we must buy approximately £269145.5 (£1000000* 26.91%) worth of futures contracts on foreign exchange. Although only the initial margin of £26914.5 (10% * £269145.5) is paid at first, we have a great benefit as we don't need to buy future contracts that would cover the hole amount invested internationally. We are hedged against the FX losses that the portfolios can incur in a week.

V. Conclusions

1. The main characteristic of foreign exchange rates is their unpredictability in the near future. Unpredictability in the movement of any financial instrument gives rise to risk and one should always to hedge against such risks;

2. Assuming non-normality of returns and using a GARCH model (i.e. Exponentially Weighted Moving Average) to estimate the variance of a portfolio will yield a more precise value form VaR; thus, making it more representative to current economic data;

3. With the help of Component VaR, one can observe how much the foreign exchange risk contributes to the VaR of a portfolio. On average, this contribution accounts for 26.91% of the Value at Risk;

4. Knowing the contributions of currency risk to the portfolio VaR is of great importance when implementing a FX hedging strategy. Cost benefits are obtained as one does not need to be protected against the whole amount invested in international assets but only for a quarter.

VI. Further Research Topics

1. To observe the impact of foreign exchange risk on a portfolio using other time periods (such as the 2000-2003 dot-com crisis, the 2003-2007 expansion period, the 2007-2009 financial crisis and all combinations of these) and compare the results to derive a more general tendency.

2. To compute and compare the costs of all main hedge strategies for foreign exchange and notice which of them would reduce the opportunity cost of capital.

3. To determine the impact of currency risk on all investments made by a fund manager (e.g. fixed income securities, money market instruments, real estate, private equity and hedge funds).

4. To study the investment preferences of fund managers to better determine the range of the weights attributed to each investment opportunities such as the ones enumerated above.

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